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Application of Liquid Silica Nutrients to Plant Growth Analysis and Rice Productivity Affected by Salt Stress (NaCl)

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ABSTRACT

The use of liquid silica nutrients under salt stress can increase plant resistance through cell wall thickening which will also affect to increase productivity. The study aims to examine the effect of liquid silica nutrients to plant growth analyze and rice productivity affected by salt stress (NaCl). The experiment used a factorial completely randomized design. The first factor was NaCl concentrations consisted of 0 dS m^{-1}, 4 dS m^{-1}, 8 dS m^{-1}, and 12 dS m^{-1}. The second factor was application of liquid silica nutrients consisted of 0.2 mL L^{-1}, 0.4 mL L^{-1}, and 0.6 mL L^{-1}. The treatments were repeated three times. Increasing the NaCl concentration to 12 dS m^{-1} when the plants were 4 weeks after planting caused a decrease in leaf area index. The addition of liquid silica nutrients with concentration up to 0.6 mL L^{-1} under saline conditions led to an increase in root shoot ratio, and the addition of liquid silica nutrients with concentration of 0.6 mL L^{-1} in salted conditions of 4 dS m^{-1} caused an increase in plant growth rate. The results showed that the leaf area index, leaf area ratio, root shoot ratio, and plant growth rate were positively correlated with plant biomass. Furthermore, the root shoot ratio had a positively correlated with productivity, the harvested index had a positively correlated with the number of productive tillers, percentage of filled grains, and rice productivity. However, the net assimilation rate and harvested index were negatively correlated with plant biomass.

Keywords:

abiotic stress; beneficial nutrients; physiology; rice; salinity

1. Introduction

Indonesia is one of the countries with the majority of the population consumes rice as a staple food. In 2019, there were 111.58 kg $capita^{-1}$ $year^{-1}$ of rice consumption in Indonesia (Kementerian Pertanian, 2019). On the other hand, Indonesia's population in 2019 is 269 million with a population growth rate of 1.19% (BPS, 2013). Based on the data by BPS (2019), Indonesia produces 54.60 million tons of milled dry grain with a conversion value to the rice of 62.74% so that the total rice consumed is 34.26 million tons. Based on these data, activity to increase rice production are needed to avoid the lack of food, especially rice.

Suboptimal land use such as saline field is one of the solutions to increase rice production. However, saline land has many obstacles such as high salt in the soil and irrigation water, high evapotranspiration causes the amount of water in the leaves decreased, strong wind, and low precipitation (Foundation, 2018; Mareza et al., 2014; Rachman et al., 2018). The plants are grown on saline condition through high osmotic and ionic stress, nutritional disorders and toxicity, and also decrease rice productivity (Radanielson et al., 2018; Shrivastava and Kumar, 2015). Some indicators that indicate crop disruption due to salinity are narrowed leaves, reduced number of productive tillers, decreased biomass production, empty grain, and decreased productivity (Zeng, 2005). Carillo et al. (2011) state that the high salinity causes disruption of the root ability to absorb water and the high salt becomes toxic for plants. It can inhibit physiological and biochemical processes such as nutrient uptake and assimilation. Based on the research of Tatar et al. (2010) some cultivars include Kiral, Yavuz from Turkey, and IR 31785-58-1-2-3-3, IR 4630-22-2 from IRRI were planted in high salt conditions will reduce plant biomass and also cause a decrease in productivity.

The use of salt resistant cultivar is one of the solutions to produce rice in the saline field. Rice cv. Dendang is a cultivar that has resistance to salinity. Balai Pengkajian Teknologi Pertanian Kalimantan Barat (2015) state that the Cultivar Dendang has resistance to salinity and also have the yield potential up to 5 tons per hectare. However, some research show that the potential yield of Dendang cultivar planted in the saline field is still low. Arini et al. (2019) reported that salt treatment at 8.35 dS m^{-1} was able to reduce the productivity of rice cv. Dendang. The EC value between 10 dS m^{-1} to 25 dS m^{-1} causes a decrease in leaf area, dry weight, and productivity. The same conditions also causes rice productivity to be only 0.2% of the yield potential (Nasrudin and Rosmala, 2021).

The addition of silica nutrients to rice planted in the saline field is thought to improve rice growth and productivity. The silica nutrient is a micronutrient that function in plants to reduce biotic and abiotic stress and thicken the cell-wall. Therefore, in plants silica nutrients also serves to help improve growth, development, and reproduction (Currie and Perry, 2007). Based on the research of Frasetya et al. (2019) silica combined with the jajar legowo system can improve the growth and rice productivity indicated by the parameters of 1,000 grains, productivity per plot, number of tillers, plant height, and yield of paddy per hill. Under saline conditions, silica can increase rice growth and lowered Na^+ ion in shoots, minor effects in roots, and silica can reduce Na^+ translocation in some of cultivars such as IR29 and Pokkali (Flam-Shepherd et al., 2018). The rice Cultivar IR 64 that given silica nutrients up to 3 mM caused an increase in weight of 100 seeds (Ikhsanti et al., 2018). The use of superior rice cultivar combined with the addition of silica nutrients is expected to be a solution in improving rice growth and production in saline conditions.

Plant physiological is important to predict rice productivity. Plant growth analysis can used to determine physiological mechanism and economic yield in plants (Gardner et al., 1991). Rice productivity will decrease affected by saline conditions and disturbing the physiological mechanism. Salinity affects stomatal closure caused leaf temperature and inhibit the development of shoot elongation (Reddy et al., 2017). Aguilar et al. (2017) state that the salinity affects a decrease in rice productivity through a decrease in the leaf area index due to the decrease of photosynthesis rate. The low photosynthesis rate causes a decrease in biomass production so that the assimilates produced by plants are slight were transplanted for filling grain. The research that discusses plant growth analysis and its correlation to rice productivity under saline condition is still limited.

Therefore, this research is important to study physiological responses on rice plants through plant growth analysis and how to interact with rice productivity. Accordingly, in the present research determined the effect of application liquid silica nutrients to plant growth analysis and rice productivity affected by salt stress (NaCl).

2. Materials and Methods

This research was conducted from March to July 2020 in greenhouse, Faculty of Agriculture, Universitas Perjuangan Tasikmalaya, 359 meters above sea level. The primary materials used in this research as follow the rice cv. Dendang. Rice cv. Dendang has resistance to salinity. Micro climate data obtained during the research include the average daily temperature between 24 ^{o}C to 37 ^{o}C with air humidiy between 50% to 80% observed using digital thermohygrometer.

The experiment was arranged in Factorial Complete Randomized Design (CRD) with two factors. The salinity levels as the first factor consisted of four levels include non-saline, 4 dS m^{-1}, 8 dS m^{-1}, and 12 dS m^{-1}. The addition of liquid silica nutrients as the second factor consisted of three levels include 0.2 mL L^{-1} SiO_2, 0.4 mL L^{-1} SiO_2, and 0.6 mL L^{-1} SiO_2. The treatment was repeated three times. Salt stress was applied in the initial vegetative phase, maximum vegetative phase, and generative phase. Salt stress level is done by dissolving NaCl with the water then measured using EC & TDS meter portable before it is applied to the soil. Liquid silica nutrients using 65% SiO2.

The planting media was prepared by mixing latosol soil and cow manure with a ratio of 1:1. The planting media that has been mixed then put into a 30 cm x 40 cm polybag (approximately 5 kg for each polybag). Along with the preparation of the planting media, Rice cv. Dendang seedlings are carried out using the tray. Rice seedlings carried out for 14 days. After 14 days, rice seedlings are transplanting to the planting media in the morning. The maintenance of rice plants includes watering, fertilized, and plant-disturb organisms controlling using insecticide made from deltamethrin, herbicide made from glyphosate, insecticide made from butyl phenyl methyl carbamate. Fertilization using NPK 16:16:16 with the doses of 300 kg ha^{-1} when the plant was 4 weeks after planting and 200 kg ha^{-1} when the plant was 8 weeks after planting. Harvesting is done when the plants are ripe physiologically with a percentage of 90%. The harvesting is done manually using sickles.

The observed variables were plant biomass (g) measured by drying all parts of the plants using the Memmert oven type UN 260 at 80 ^{o}C for 48 hours. The plant biomass was observed by using digital scale when the plants were 4 weeks after planting, 8 weeks after planting, and at the harvest. Number of productive tillers, number of grains per panicle, percentage of filled grain (%), and rice productivity (ton Ha^{-1}) were observed after plants harvested. Leaf area (cm^2) measured by drew the leaves on millimeter blocks paper, then counted the leaf area was drawn. The data of leaf area was used to calculate several parameters in plant growth analysis. Leaf area index measured by measuring the leaf area per plant with a certain spacing. After the data was obtained, then it calculated using the equation I (Gardner et al., 1991)

$$\text{Leaf area index (LAI)} = \frac{1}{field\ area} \times \text{leaf area} \text{ .... (Equation I)}$$

Leaf area ratio measured by measuring the leaf area per plant and plant biomass. After the data was obtained, then it is calculated using the equation II (Gardner et al., 1991)

$$\text{Leaf area ratio (LAR) (cm}^2\text{ g}^{-1}) = \frac{\left(\frac{leaf\ area\ at\ 8\ wap}{plant\ biomass\ at\ 8\ wap}\right)+\left(\frac{leaf\ area\ at\ 4\ wap}{plant\ biomass\ at\ 4\ wap}\right)}{2} \text{ .... (Equation II)}$$

Root canopy ratio measured by measuring the root dry weight and canopy dry weight using digital scale. After the data was obtained, then it is calculated using the equation III (Gardner et al., 1991)

$$\text{Root canopy ratio (RCR)} = \frac{root\ dry\ weight}{canopy\ dry\ weight} \text{ .... (Equation III)}$$

Plant growth rate (PGR) measured by weighing the plant biomass per plant at a certain time. After the data was obtained, then it is calculated using the equation IV (Gardner et al., 1991)

$$\text{Plant growth rate (PGR) (g m}^{-2}\text{ week}^{-1}) = \frac{1}{Ga} \times \frac{W2-W1}{T2-T1} \text{ .... (Equation IV)}$$

Net assimilation rate measured by measuring the leaf area per plant and the weight of plant biomass. After the data was obtained, the it is calculated using the equation V (Gardner et al., 1991)

$$\text{Net assimilation rate (NAR) (g dm}^{-2}\text{ week}^{-1}) = \frac{W2-W1}{T2-T1} \times \frac{\ln La2-\ln La1}{La2-La1} \text{ .... (Equation V)}$$

Notes: W2 is the plant biomass at 8 wap and harvest; W1 is the plant biomass at 4 wap and 8 wap; La2 is the leaf area at 8 wap; La1 is the leaf area at 4 wap; T2 is time of observed at 8 wap and at the harvest; T1 is the time of observed at 4 wap and 8 wap; and Ga is field area.

Harvest index measured by the dried grain per clump was weighed using a digital scale of 500 x 0.01 g. The plant biomass per clump that has been dried is weighed using a digital scale too. After the data was obtained, then it is calculated using the equation VI (Gardner et al., 1991)

$$\text{Harvest index (HI)} = \frac{the\ dried\ grain\ per\ clump\ (g)}{plant\ biomass\ per\ clump\ (g)} \text{ .... (Equation VI)}$$

The data measured by analysis of variance (ANOVA). If there are significantly different between each treatment, then proceed with Duncan's multiple range test at 5% error level. The correlation analysis using Pearson correlation to determine the relationship between plant growth analysis variables with the rice yield variables (Gomez and Gomez, 1995). The data test by using the Statistical Tools for Agricultural Research (STAR) version 2.0.1 and Microsoft excel.

3. Results and Discussion

3.1 General conditions in the research area

The research used latosol soil mixed with cow manure. Based on the result of tests conducted at Balai Pengkajian Teknologi Pertanian Yogyakarta, the soil content shown in Table 1. During the research, there were some of obstacles caused by *Caelifera* and *Leprocorisa oratorios*. The *Caelifera* with an attack rate approximately 50% in plants during the vegetative phase. The *Caelifera* attack cause leaves to be damaged, thereby reduced the photosynthesis rate. However, the *Caelifer*a attack were controlled used insecticide made from deltamethrin. The *Leprocorisa oratorios* also attacks the plants during the reproduction phase. This pest attack causes many rice grains to be empty. Pest controlled used insecticide made from butyl phenyl methyl carbamate. The attack rate of *Leprocorisa oratorius* to plants approximately 60%.

Table 1. The soil content used in the research

Parameters	Unit	Value	Criteria
pH H_2O		7.48	Neutral
C-organic	%	1.09	Low
N-available	%	1.02	Very high
K-available	ppm	78	Very high
P_2O_5	ppm	244	Very high
N-total	%	0.35	Medium
P2O5 potential	mg $100g^{-1}$	122	Very high
K2O potential	mg $100g^{-1}$	783	Very high

Source: Balai Pengkajian Teknologi Pertanian Yogyakarta (2020).

3.2 Effect of application of liquid silica nutrients to plant growth analyze and rice productivity affected by salt stress (NaCl)

Leaf is one of the organs in plants that have main function in plant growth and development as a source or place for photosynthesis activity to produce assimilates. The narrow leaves will produce low assimilates, vice versa. Table 2 showed that the leaf area index at 4 weeks after planting was significantly different when treated by salinity. The higher salinity level will decrease the leaf area index. However, the addition of silica concentration did not significantly affect the leaf area index at 4 weeks after planting. The salinity levels and the addition of silica concentration was not significantly affected to the parameters include leaf area index at 8 weeks after planting, leaf area ratio, and root canopy ratio at 4 weeks after planting. Table 2 showed that there was an interaction between salinity and the addition of silica concentrations treatments to the root canopy ratio of rice cv. Dendang at the harvest. The silica concentration of 0.6 mL L^1 under non-saline condition and the addition of 0.4 mL L^{-1} silica concentration under 4 dS m^{-1} NaCl concentration produces the highest root canopy ratio compared to the other treatment interactions.

Based on Table 2, increase of NaCl concentration (8 dS m^{-1} to 12 dS m^{-1}) causes a decrease in the leaf area index. The decrease in leaf area under salinity conditions causes the photosynthesis rate to be low. The narrowing of leaf due to high salinity causes the process of transpiration and respiration to increase (Adlian et al., 2020). The decrease in leaf area index causes a decrease in plant biomass, vice versa. Based on the correlation analysis (Table 5) shows that leaf area index is positive correlation to plant biomass (r= 0.78). Furthermore, an increase in silica concentration (0.4 mL L^{-1} to 0.6 mL L^{-1}) under salt stress (up to 4 dS m^{-1}) causes plant growth rate during the initial vegetative phase to increase compared to other treatment interactions. The increase in plant growth rate due to an increase in leaf area index, based on the correlation analysis shows that leaf area is positive correlation to plant growth rate (r= 0.70).

Table 2. Effect of application of liquid silica nutrients to leaf area index at 4 wap and 8 wap, leaf area ratio (cm^2 g^{-1}), and root canopy ratio at 4 wap under salt stress (NaCl).

Treatment	Leaf area index		Leaf area ratio (cm^2 g^{-1})	Root canopy ratio in 4 wap
	4 wap	8 wap		
NaCl concentration				
0 dS m^{-1}	0.92^{ab}	11.28	123.34	0.39
4 dS m^{-1}	1.32^{a}	7.90	307.59	0.36
8 dS m^{-1}	0.32^{b}	9.43	204.59	0.31
12 dS m^{-1}	0.58^{b}	10.77	152.21	0.21
Silica concentration				
0.2 mL L^{-1}	0.60	9.39	181.74	0.30
0.4 mL L^{-1}	0.81	8.63	261.12	0.39
0.6 mL L^{-1}	0.95	11.52	147.94	0.27
Interaction	**-**	**-**	**-**	**-**
CV (%)	**24.28***	**27.11***	**44.34***	**12.48***

Notes: - (no interaction); * (CV with the data was transformed); wap (weeks after planting); the number followed by the same letter in the same column has no significantly different in the DMRT α 5% error level.

Table 3 showed that there was an interaction between salinity and the addition of silica concentrations treatments to the root canopy ratio of rice cv. Dendang at 8 weeks after planting. Rice planted under non-saline and salinity of 12 dS m^{-1} with the addition of 0.2 mL L^{-1} to 0.6 mL L^{-1} silica concentrations produces the same root canopy ratio. The addition of 0.4 mL L^{-1} to 0.6 mL L^{-1} silica concentration under saline conditions of 4 dS m^{-1} to 8 dS m^{-1} causes an increase in the root canopy ratio. Furthermore, the addition of 0.2 mL L^{-1} silica concentration under non-saline and salinity of 12 dS m^{-1} was not significantly different in the root canopy ratio. The addition of 0.4 mL L^{-1} to 0.6 mL L^{-1} silica concentrations under non-saline up to 8 dS m^{-1} causes a higher root canopy ratio, whereas the addition of 0.4 mL L^{-1} to 0.6 mL L^{-1} silica concentrations under 12 dS m^{-1} saline conditions cause a decrease in the root canopy ratio.

The treatments of NaCl concentrations and silica application did not affect the leaf area ratio and root canopy ratio. It is suspected that when the plants entering initial vegetative phase is still able to adapt to salinity conditions. The high of N-available content also did not significantly affect to leaf area ratio even though at the saline condition (12 dS m^{-1}). Indriyati et al. (2008) state that the organic material mixed together with the planting media will experience of mineralization then become N-available to plants. In addition, the silica functions can increase the resistance of rice plant to salt stress. The plants will manipulate a series of physiological and biochemical response to produce secondary metabolites. These compounds will be actively involved in the mechanism of plants to defend themselves in biotic and abiotic stress (Dewi et al., 2014).

Table 3 showed that there was an interaction between salinity and the addition of silica concentrations treatments to the plant growth rate of rice cv. Dendang at 0-4 weeks after planting. The addition of higher silica concentrations under non-saline to 4 dS m^{-1} salinity conditions cause an increase in plant growth rate. Whereas, under 8 dS m^{-1} to 12 dS m^{-1} salinity conditions with the addition of various silica concentrations, it will produce the same plant growth rate.

Table 3. Effect of salt stress (NaCl) and application of liquid silica nutrients on rice cv. Dendang rice to root canopy ratio at 8 wap, and at the harvest, and plant growth rate at 4 wap.

	NaCl concentration	Silica concentration			Average
		0.2 mL L^{-1}	0.4 mL L^{-1}	0.6 mL L^{-1}	
Root canopy ratio at 8 WAP	0 dS m^{-1}	0.171^{b}	0.301^{ab}	0.215^{b}	0.230
	4 dS m^{-1}	0.173^{b}	0.428^{a}	0.291^{ab}	0.297
	8 dS m^{-1}	0.170^{b}	0.339^{ab}	0.292^{ab}	0.267
	12 dS m^{-1}	0.350^{ab}	0.248^{b}	0.259^{b}	0.286
	Average	0.279	0.265	0.264	0.269 (+)
	CV (%)		**6.34***		
Root canopy ratio at the harvest	0 dS m^{-1}	0.164^{b}	0.096^{b}	0.358^{a}	0.206
	4 dS m^{-1}	0.223^{b}	0.284^{ab}	0.182^{b}	0.230
	8 dS m^{-1}	0.107^{b}	0.139^{b}	0.132^{b}	0.126
	12 dSm^{-1}	0.147^{b}	0.091^{b}	0.178^{b}	0.139
	Average	0.160	0.153	0.213	0.175(+)
	CV (%)		**5.50***		
Plant growth rate at 0-4 WAP	0 dS m^{-1}	0.990^{bc}	1.928^{b}	3.906^{a}	2.275
	4 dS m^{-1}	0.989^{bc}	0.674^{bc}	2.923^{ab}	1.528
	8 dS m^{-1}	0.344^{bc}	0.433^{bc}	0.188^{c}	0.321
	12 dSm^{-1}	1.151^{bc}	1.063^{bc}	0.685^{bc}	0.966
	Average	0.868	1.519	1.431	1.273(+)
	CV (%)		**29.54***		

Notes: + (there are interaction); * (CV with the data was transformed); WAP (weeks after planting); Numbers followed by different letter has significantly different in the DMRT α 5% error level.

When the plant enters the maximum vegetative and generative phases, application silica with concentration 0.4 mL L^{-1} up to 0.6 mL L^{-1} causes an increase in the root canopy ratio compared to other treatment interactions (Table 3). In this case, silica plays a role to improve rice plant resistance in salt stress (up to 8 dS m^{-1}). The rice resistance through the root growth and inhibits the canopy growth. This is an escape mechanism in plants against abiotic conditions. Based on the research of Ikhsanti et al. (2018) the application of silica (1 mM) to rice plants under saline condition (4 dS m^{-1}) led to an increase in root to canopy ratio. The increased in root to canopy ratio reduced salt absorption through the transpiration, so that the growth is focused on root growth and canopy growth is inhibited. Table 4 showed that salinity and silica concentrations treatments was not affects to the parameters include plant growth rate at 4-8 weeks after planting, plant growth rate at 8-17 weeks after planting, net assimilation rate, and harvest index.

Table 4. Effect of application of liquid silica nutrients to plant growth rate at 4-8 wap, and 8-17 wap (g m^{-2} $week^{-1}$), net assimilation rate (g dm^{-2} $week^{-1}$), harvest index under salt stress (NaCl).

Treatment	**Plant growth rate (g m^{-2} $week^{-1}$)**		**Net assimilation rate (g dm^{-2} $week^{-1}$)**	**Harvest index**
	4-8 wap	**8-17 wap**		
NaCl concentration				
0 dS m^{-1}	32.58	64.05	0.92	0.25
4 dS m^{-1}	23.81	58.86	1.56	0.28
8 dS m^{-1}	27.81	41.35	1.11	0.30
12 dS m^{-1}	24.04	48.79	0.81	0.29

Silica concentration				
0.2 mL L^{-1}	25.30	53.82	1.53	0.27
0.4 mL L^{-1}	25.08	52.17	0.87	0.24
0.6 mL L^{-1}	30.80	53.81	0.90	0.33
Interaction	**-**	**-**	**-**	**-**
CV (%)	**29.76***	**21.64***	**30.69***	**7.83***

Notes: - (no interaction); * (CV with the data was transformed); WAP (weeks after planting); the number followed by the same letter in the same column has no significantly different in the DMRT α 5% error level.

Salt stress and silica application have no significant effect to net assimilation rate and harvest index. It is due to the saline condition, plants more allocated assimilate for root growth. The limited assimilate for canopy growth causes plant biomass also becomes limited. It will be affected to net assimilation rate and harvest index. Under saline conditions, there is a change metabolism in plants and causes a decrease in photosynthesis rate due to osmotic and ionic stress by NaCl (Amartani, 2019). Silica also did not have a significant effect to net assimilation rate and harvest index. It is suspected that the silica concentration given relatively low so it did not affect the net assimilation rate and harvest index on rice plants.

The correlation analysis in this experiment was conducted to determine the relationship between the variables. Table 5 showed that there was positive correlation between plant growth analysis and rice productivity shown by leaf area index to plant biomass (r= 0.70 and r= 0.78), leaf area ratio to plant biomass (r= 0.27), root canopy ratio to plant biomass (r= 0.39), root canopy ratio to rice productivity (r= 0.30), and plant growth rate to plant biomass (r= 1, r= 0.99, and r= 0.97). Furthermore, the harvest index also positively correlated to the number of productive tillers (r= 0.47), to percentage filled grain (r= 0.40), and to rice productivity (r= 0.58). Whereas, two parameters were negative correlation shown by net assimilation rate and harvest index to plant biomass (r= -0.29) and (r= -0.42), respectively.

Some of plant growth analysis are positive correlation to biomass production, include leaf area index, root canopy ration, and plant growth rate. This illustrates the number of assimilates produced by plants to support the growth and rice production. The high biomass production will increase rice productivity, based on the correlation analysis plant biomass is positive correlation to productivity (r= 0.42). The plant biomass is produced by plants when entering its growth phase, partly to support the plant growth and partly for filling grain. Tunçtürk et al. (2011) state that the plant biomass shows the number of assimilates deposits during plant growth and it affected by the photosynthesis rate. Furthermore, the increase of harvest index was followed by an increasing in the number of productive tillers, percentage filled grain, and productivity. Some plant growth analyze were negative correlation to biomass production, include net assimilation rate (r= -0.29) and harvest index (r= -0.42), respectively. This correlation occurs due to most of the assimilate are transplanted and used by plants for root growth.

Accordingly, in this present research the addition of liquid silica influences in several physiological characteristics of plants, include plant resistance to salinity stress. This is indicated by several plant growth analysis that are significantly different when the plant is given salinity stress. There is a tolerance limit for rice cv. Dendang to withstand salinity stress so silica is needed to strengthen its resistance to salinity.

Table 5. The correlation matrix between plant growth analysis and rice productivity of rice cv. Dendang with application of silica nutrients under salt stress (NaCl).

Variable	LAI 1	LAI 2	LAR	RCR 1	RCR 2	RCR 3	PGR 1	PGR 2	PGR 3	NAR	HI	NoPT	NoGP	%FG	BIO 1	BIO 2	BIO 3	PRO
LAI 1	1*																	
LAI 2	0.01ns	1*																
LAR	0.17ns	0.27*	1*															
RCR 1	-0.02ns	-0.05ns	-0.15ns	1*														
RCR 2	0.08ns	0.13ns	-0.01ns	-0.14ns	1*													
RCR 3	0.02ns	-0.01ns	0.10ns	0.07ns	-0.29*	1*												
PGR 1	0.70*	0.06ns	-0.26*	0.12ns	0.12ns	-0.12ns	1*											
PGR 2	0.11ns	0.78*	0.30*	0.05ns	0.19ns	-0.02ns	0.03ns	1*										
PGR 3	0.18ns	-0.09ns	-0.05ns	-0.08ns	0.34*	-0.14ns	0.20ns	-0.19ns	1*									
NAR	-0.32*	-0.29ns	-0.08ns	0.12ns	0.21ns	0.34*	-0.29*	-0.06ns	-0.22ns	1*								
HI	-0.06ns	0.04ns	0.12ns	-0.28*	-0.26*	0.40*	-0.17ns	0.03ns	-0.42*	0.01ns	1*							
NoPT	0.37*	-0.03ns	0.04ns	-0.36*	-0.05ns	0.21ns	0.23ns	-0.09ns	0.18ns	-0.22ns	0.47*	1*						
NoGP	-0.15ns	-0.02ns	0.07ns	0.15ns	0.14ns	-0.15ns	-0.16ns	-0.01ns	0.10ns	0.03ns	-0.11ns	-0.60*	1*					
%FG	0.09ns	0.10ns	-0.08ns	-0.07ns	0.07ns	0.10ns	0.11ns	0.04ns	0.20ns	-0.08ns	0.40*	0.37*	-0.36*	1*				
BIO 1	0.70*	0.06ns	-0.26*	0.12ns	0.12ns	-0.12ns	1*	0.03ns	0.20ns	-0.29*	-0.17ns	0.23ns	-0.16ns	0.11ns	1*			
BIO 2	0.18ns	0.78*	0.27*	0.06ns	0.20ns	-0.03ns	0.14ns	0.99*	-0.17ns	-0.09ns	0.01ns	-0.06ns	-0.02ns	0.05ns	0.14ns	1*		
BIO 3	0.22ns	0.09ns	0.02ns	-0.06ns	0.39*	-0.15ns	0.24ns	0.04ns	0.97*	-0.24ns	-0.42*	0.17ns	0.09ns	0.22ns	0.24ns	0.07ns	1*	
PRO	0.20ns	0.11ns	0.20ns	-0.32*	0.11ns	0.30*	0.04ns	0.11ns	0.39*	-0.18ns	0.58*	0.59*	0.05ns	0.45*	0.04ns	0.11ns	0.42*	1*

Notes: ns (not significant); * (significant); LAI (leaf area index); LAR (leaf area ratio); RCR (root canopy ratio); PGR (plant growth rate); NAR (net assimilation rate); HI (harvest index); NoPT (the number of productive tillers); NoGP (the number of grains per panicle); %GF (percentage of grain filled); BIO (plant biomass); PRO (rice productivity).

4. Conclusion

The increase of salinity on 8 dS m^{-1} to 12 dS m^{-1} causes a decrease in leaf area index (LAI) at 4 weeks after planting. However, salinity and silica concentration treatments were not significantly affected to leaf area at 8 weeks after planting, leaf area ratio, root canopy ratio at 4 weeks after planting, plant growth rate, net assimilation rate, and harvest index. Furthermore, silica application of 0.4 mL L^{-1} to 0.6 mL L^{-1} under non-saline to 8 dS m^{-1} causes an increase in the root canopy ratio and also silica application of 0.6 mL L^{-1} under non-saline to 4 dS m^{-1} causes an increase in the plant growth rate. The plant growth analysis was positive correlation to rice productivity shown by leaf area index to plant biomass (r= 0.70 and r= 0.78), leaf area ratio to plant biomass (r= 0.27), root canopy ratio to plant biomass (r= 0.39), plant growth rate to plant biomass (r= 1, r= 0.99, and r= 0.97), root canopy ratio to rice productivity (r= 0.30), and harvest index to the number of productive tillers, percentage filled grain, and rice productivity (r= 0.47), (r= 0.40), and (r= 0.58), respectively. However, the plant growth analysis was negative correlation to rice productivity shown by net assimilation rate and harvest index to plant biomass (r= -0.29) and (r= -0.42), respectively.

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